Assessment of Heavy Metal Contamination in Food Basket and Drinking Water with Potential Human Health Risks in Urban Area

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Certificate

I hereby declare that the short synopsis "**Assessment of Heavy Metal Contamination in Food Basket and Drinking Water with Potential Human Health Risks in Urban Area**" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Biotechnology under School of Engineering and Technology of Manav Rachna International Institute of Research and Studies, Faridabad during the Academic Year 2024-25. It is a bonafide record of original work carried out under the supervision of Dr. Sarita Sachdeva, Professor, Department of Biotechnology, School of Engineering & Technology, Manav Rachna International Institute of Research and Studies and Dr. Girija Bharat, Director, Mu Gamma Consultants Pvt. Ltd. and has not been submitted in full or part to any other University or Institute for degree or diploma. Further, it is certified that short synopsis is plagiarism-free free and proof has been submitted.

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Abstract

Heavy metals such as mercury, cadmium, lead, and arsenic are pervasive environmental pollutants that present significant health risks, particularly owing to their presence in food, water, and other ingested items. This study investigates the sources, pathways, and accumulation levels of these toxic and essential metals as well in the urban food basket (comprising fruits, vegetables, pulses, cereals, milk, and other animal products) and drinking water (both supply and packaged) within the capital city of Delhi. Industrial activities, agricultural practices, and environmental pollution are often identified as the primary sources of contamination, with recent studies indicating alarming concentrations of these metals in various food sources. The study also focuses on the health impacts of metals by assessing the carcinogenic and non-carcinogenic risks to both children and adults, considering their varying exposure levels. This is crucial, as vulnerable groups, including pregnant women, children, and the elderly, face heightened risks due to their higher susceptibility to the toxic effects of these metals. In addition, the study evaluates the toxicity of these metals in human cell lines, assessing cytotoxic effects and the potential for long-term damage such as oxidative stress and DNA damage, as demonstrated in recent cell-based studies. Lastly, the study reviews existing regulatory frameworks and guidelines surrounding heavy metal contamination in food. It emphasizes the need for robust monitoring systems, improved agricultural practices, and food processing techniques to mitigate contamination risks. The study promotes a cohesive, interdisciplinary strategy that unites environmental scientists, food producers, public health specialists, and policymakers to enhance food safety regulations.

Keywords: *Carcinogenic risk, Food contamination, Heavy metals, Human health, Permissible limits*

Table of Contents

	Certificate	i
	Abstract	ii
	Table of Contents	iii

S.No.	Contents	Page No.
1	Introduction	5
2	Literature Review	5-9
3	Study Area	9-10
4	Research Objectives	10
5	Research Methodology	11-17
6	Expected Outcome of the Research	17-18
7	Significance	18
	References	19-24
	Similarity Verification	
	Certificate	
	Annexure I- Timeline	
	Annexure II- Published Paper (Scopus, Q1)	

Introduction

Food security under the United Nations' Sustainable Development Goals (SDGs) is an assorted concept and is likely to be accomplished only once each individual, outside any economic or cultural judgment, always has access to sufficient and safe food to lead a healthy and active life (FAO, 2015; UN DESA, 2024). However, globally, policy planning is focused on fighting the hunger stress owing to famines and lack of resources, especially in developing countries. Major hindrance in attaining food security worldwide and in India in particular is the focus on increasing the quantity and availability of food which results in unethical practices such as increasing food on polluted land or consuming unprocessed wastewater for irrigation. These methods cause infections, hazardous poisons, and heavy metals to be transferred to food crops. High quantities of heavy metals have been reported in several global verified reports to be present in food crops and poultry products, including meat, eggs, and milk (Kumar et al., 2023) (Gupta et al., 2012; Babu et al., 2018). Additionally, reports have confirmed similar trends in other developing regions, where polluted irrigation water is a major source of contamination (Kumar et al., 2023; Singh et al., 2023). Long-term consumption of such contaminated food has been linked to various health issues, including neurological disorders, kidney damage, and even cancer (Bhowmick et al., 2022). The prolonged ingestion of foods containing hazardous levels of heavy metals by humans can cause several biological and biochemical processes in the human body to malfunction. Thus, mere availability of food doesn't aid in attaining food security, the concept must evolve to include safe, balanced diet with all the nourishment required without any contamination (FAO, 2015).

Review of Literature

Metals have a ubiquitous presence in the earth's crust and are spread into the environment through erosion due to wind and water as dust or leached into rivers. All of these anthropological activities—such as sewage irrigation, adding manures, fertilizers, and pesticides, demolition and construction, tyre abrasion, and normal wear and use on vehicles—release more metals into the environment than do these natural processes (Patel et al, 2024; Tariq et al., 2022; Chakraborty et al., 2020). The group of metallic elements known as heavy metals is heterogeneous and consists

of different biological roles and chemical properties. They have a higher density than water and are characterized by specific weight of more than 5 gcm^{-3}, their heaviness and toxicity are related as they can induce toxicity at low doses (Kumar et al., 2023; Chakraborty et al., 2019). Four categories can be used to classify heavy metals: cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn) are considered essential elements because plants need these metals in low concentrations as growth-promoting nutrients (Khan et al., 2020; Rajan et al, 2024). However, exposure to high concentrations of these elements has been documented to cause cellular or systemic disorders and is considered toxic (Mehta et al., 2021). Metals like Barium (Ba), Aluminum (Al), Lithium (Li) are non-essential elements whereas Tin (Sn), Chromium (Cr) and Nickel (Ni) are essential for animals. Hazardous/ Highly toxic metals like Mercury (Hg), Lead (Pb), Arsenic (As) and Cadmium (Cd), have the ability to bioaccumulate into the food chain due to their environmental persistence (Khan et al., 2020; Chakraborty et al., 2019). Metals play a vital role in many biological processes, including signalling, homeostasis, and enzyme catalysis. They are an essential component of our environment. Due to their propensity for bioaccumulation and biomagnification throughout the food chain, exposure to higher concentrations of certain metals has been shown to have harmful effects. The method of exposure, the dosage, the chemical species, the exposed person's age, gender, heredity, and nutritional state are all factors contribute to toxicity of heavy metals. (Sharma et al, 2024). Acute poisoning occurs when a high amount is consumed quickly, while chronic poisoning, also known as bioaccumulation, occurs when a low exposure occurs over an extended period of time. These effects are related to the dose and timing of consumption (Sharma & Nagpal, 2020; Li et al., 2022, Singh, et al 2024). Since they are thermostable and non-biodegradable, they can quickly build up to hazardous concentrations and are thought to be the main pollutant of leafy green crops (Mehta et al., 2021).

Estimates indicate that 10% of the world's population relies on wastewater-irrigated produce. Increased food demand in developing countries has pushed farmers to adopt low-cost methodologies, keeping high crop yields in mind. Approximately 200 million farmers are believed to be using different forms of wastewater (treated, partially treated, untreated) in agricultural irrigation (Manzoor et al., 2018; Zhao et al., 2021; Karini, et al 2023). Although a

significant amount of vital plant nutrients is present in wastewater, which may lessen the requirement for synthetic fertilizers; however, it also poses environmental and health risks due to their capacity of supplying wide array of contaminants, such as pathogens, synthetic chemicals, and heavy metals like cadmium, chromium, nickel, lead, etc. (Zhao et al., 2021; Manzoor et al., 2018). An important factor in the notable rise in heavy metal levels in soil and crops is irrigation with raw sewage water. This practice can raise specific metal levels in soil by 2% to 80% and in crops by 14% to 90% (Ali et al., 2020; Kumar et al., 2021). Sources of heavy metals for crops are their growth media (soil, air, nutrient solutions), from which roots or leaves absorb the metals, seriously harming not only plants but also animals when ingested by secondary and tertiary consumers (Jaishankar et al., 2014; Manzoor et al., 2018; Wan, et al 2024). Long-term use of wastewater for crop irrigation causes toxic metal accumulation in the soil, which inhibits soil function and causes plant toxicity and food chain pollution that compromises food quality and safety (Khan et. al, 2008). Vegetables that have been irrigated with wastewater tend to have higher levels of heavy metals in their edible sections than grain or fruit crops, therefore eating them is cause for concern (A. Sharma & Nagpal, 2020). In a study in long-term wastewater irrigated area in Varanasi in India, Cd, Pb and Ni concentrations were above the permissible limits in all the vegetable samples tested (Singh et al., 2020). A similar study in sewage irrigated areas of Agra, India found Zn concentration to be highest in sewage whereas Cd was found in traces (Verghese, 2020). These studies are in conjunction with and can potentially explain the studies from China and Egypt which found the highest concentration of Zn and lowest of Cd in vegetable samples from marketplaces (Meshref et al., 2020; Khan et al., 2008). In wastewater-irrigated agricultural sites in dry tropical India, concentrations of Cd, Cu, Pb, Ni, and Cr increased by more than 100% (Khan et al., 2020). In agricultural fields irrigated by industrial wastewater in Vadodara, Gujarat, India concentration of heavy metals was found to be significantly lower for tube well irrigated fields than those irrigated with wastewater. The heavy metal concentrations found in soil were Fe>Mn>Zn>Cd>Cu>Pb>Cr>As (Tiwari et al., 2021).

Plants not only absorb harmful metals through their roots but also from deposits on their exposed surfaces when they are in an air-polluted environment (Jaishankar et al., 2014; Meshref et. al, 2020). A study conducted by Iavicoli et al., 2009 in select areas of Agra, India investigated the absorption/ accumulation of air borne heavy metals in vegetables. Same study determined levels

of Cd, Cr, Ni and Zn in washed and unwashed test samples, reporting hazardous element concentrations in unwashed samples were greater than in cleaned samples. Increased concentrations of heavy metals have been found attributable to atmospheric deposition on vegetables sold in the Riyadh city market in Saudi Arabia (Manzoor et al., 2020). Accumulation of Pb, Cr, and Cd in high concentration due to atmospheric deposition in leafy vegetables has been reported (Iavicoli et al., 2009; Suruchi & Jilani, 2011). There is a positive relationship between the deposition of atmospheric metal and increased concentrations of heavy metals in topsoil and plants (Meshref et. al, 2020). A study conducted in Pakistan's Swat District discovered a correlation between the metal concentrations in the soil and the metal concentrations in vegetables grown there, including Cr, Cu, Mn, Ni, and Zn (Khan et al., 2013). Wear and tear on motor vehicles, automobile emissions are major causes of heavy metal pollution. All pollutants emitted on the road get washed off by road surface water runoff and accumulate as roadside sediments. Cd and Pb are highly associated with automobile emissions and tyre wear and tear thus, it can be appropriately concluded that contamination of Cd and Pb in roadside sediments found by Pradhan & Kumar, 2014 can be attributed to high anthropogenic input. Cu and Zn on the other hand can be possibly sourced back to anti-fouling products used in vehicular paints and vehicle scrap parts. This study along National Highway-2 (Delhi to Kolkata, India) found Zn to be in high concentration in both roadside deposited sediment and road surface water runoff. Similar studies showed Cd and Zn in soil and vegetation in Nigeria along the roadsides and found them in high concentrations thus concluding automobiles to be a significant source of these metals in the environment near highways (Peter et. al, 2020).

One of the planet’s most precious and significant natural resources, water is abundant and free of charge. However, the issue of industrialization, urbanization, and excessive exploitation of the world's natural and man-made resources has been exacerbated by the population growth that has occurred everywhere in the world. This has led to an acceleration of the pollution problem of many kinds. Water resources that were previously abundant are now overextended due to the water usage for agriculture, drinking, household, and commercial needs. The quality of water from nature has been further compromised by over-exploitation. Water quality has been lowered by pollution from non-point sources of water like landfills and surface runoff. Furthermore,

untreated or inadequately treated home, municipal, institutional, and industrial effluents are point sources of contamination due to the presence of heavy metals to a large extent (Prasad et al., 2022). Research conducted in Delhi's Yamuna floodplains found that 53% and 44% (HPI >100) of groundwater samples were in high-risk zones based on the heavy metal pollution index (HPI) measured during the pre- and post-monsoon seasons. The degree of contamination (Cd) indicated that 53% of pre-monsoon and 56% of post-monsoon samples were extremely polluted.

Because heavy metals are a part of the food chain and can have sublethal impacts on aquatic and human life, it is crucial to research heavy metals in water (K. Sharma et al., 2022). The effects of water quality are more apparent, especially in the summer when drinking water sources dry up from little to no rainfall and high turbidity from an increased rate of precipitation.

Study area

Delhi, the fifth most populous city in the world resides 30.3 million people in the urban area, 10.9 of which live in the city area (PopulationStat 2024). Heavy migration pattern has resulted in making the city culturally and ethnically diverse which also reflects in the food consumption patterns (Goswami, 2018). The Indian food basket varies substantially due to geographical, cultural, religious and economic diversity. The food basket in Delhi is an amalgamation of all these diverse consumption patterns.

According to the Economic Survey of Delhi 2017–18, the cropped area in Delhi has decreased by more than 34% since 2000–01 and is limited to vegetable cultivation at five major sites in Delhi (Bhardwaj et. al, 2017). The Yamunapusta site is vulnerable to contamination due to airborne deposition from a nearby coal-fired thermal power plant. The primary sources of contamination at the Okhla site are the thermal power plant and sewage water. Sewage water is the primary cause of contamination in Najafgarh, whereas industrial emissions are the primary cause in Ballabhgarh. Given the dearth of industries in Alipur, the primary sources of heavy metals are agrochemicals (fungicides and micronutrients) (Singh & Kumar, 2006). The municipal dumpsites are also a major source of heavy metals for soil and groundwater with their informal recycling activities, and the leaching of metals from waste to soil (Chakraborty et al., 2019).

Yamuna River is the principal tributary of the Ganges, holding significant economic value, supplying water to around 57 million individuals, and constituting over 70% of Delhi's water supply (Rajan et al., 2024). Over 90% of the total water demand in some districts is met by the river, which is the main supply of water for home and agricultural uses for the people of India. Regretfully, untreated or poorly treated wastewater containing undesired amounts of harmful metals has been released into the Yamuna River, causing significant pollution to the river, its major tributaries, and its catchment region in recent years.

Objectives

1. To estimate toxic and essential heavy metals in food basket i.e fruits, vegetables, pulses, cereals, milk/other animal products, and drinking water (supply and packaged) in Delhi for identification of potential sources with the quantum of contamination.
2. To integrate data on heavy metal concentrations with consumption patterns to estimate carcinogenic and non-carcinogenic risks in adult and children.
3. To estimate toxic heavy metals in soil irrigated with wastewater and associated growing vegetables in Yamuna Belt in Delhi.
4. Study of toxicity of heavy metals in human cell lines for assessment of impact on Human Health.
5. To study existing regulatory frameworks and guidelines related to heavy metals in food consumption.

METHODOLGY

1. **To estimate toxic and essential heavy metals in food baskets i.e fruits, vegetables, pulses, cereals, milk/other animal products, and drinking water (supply and packaged) in Delhi for identification of potential sources with the quantum of contamination.**

The Indian food basket varies substantially due to geographical, cultural, religious and economic diversity. The food basket in Delhi is an amalgamation of all these diverse consumption patterns. On average an Indian food basket comprises of fruits, vegetables, pulses, cereals and milk/other animal products, two to four food items will be sampled from each category. Food items will be selected based on their consumption frequency in Indian urban and rural populations. The food samples will be analyzed for quantitative estimations of an extensive list of essential and toxic heavy metals.

Heavy metals – Toxic (As, Cr, Cd, Pb, Hg, Ni) and Essential (Zn, Co, Mn, Cu, Se, Mo)

Samples of each food item would be thoroughly homogenized using an electric blender and subsequently transferred to a pre-cleaned and blow-dried glass jar (rinsed with acetone). Sample analysis would be done by ICP-MS after sample mineralization in a microwave decomposition system. About 0.3 g of each matrix will be digested with 4 ml of concentrated HNO_3 and 2 ml H_2O_2 in PTFE vessels. Samples will be digested at 200 °C for 20 minutes with temperature ramping in 20 minutes. Finally, mineralized samples will be diluted to 50 ml with Milli-Q water. To quantify trace metals in digested material, an Agilent 7700x ICP-MS apparatus outfitted with a Micro Mist concentric nebulizer, a Scott double-pass spray chamber, a quartz torch with a 2.5 mm i.d. injector, and nickel sampling/skimmer cones would be utilized.

Sample Processing

- **Water Samples**

Determination of the selected elements in water samples will be performed by inductively coupled plasma mass spectrometry (ICP-MS) (Agilent 7700x ICP-MS, Agilent technologies) directly from samples acidified to 0.5% (v/v) HNO3. The matrix of samples for Hg analysis will be modified by addition of gold (III) chloride (final concentration 200 Au µg/L) for suppression of Hg memory effects in sample introduction system.

- **Food Samples**

Determination of the selected elements (excluding Hg) in food samples was performed by ICP-MS (Agilent 7700x ICP-MS, Agilent technologies) after sample mineralization in a microwave decomposition system (MARS 6, CEM Corporation). About 0.3 g of each matrix was digested with 4 ml of concentrated HNO_3 (Merck, suprapure) and 2 ml H_2O_2 (Merck, empsure) in PTFE vessels (Xpress plus 110 ml, CEM).

Statistical Analysis

Pearson correlation matrix was applied to identify the relationship among the concentrations of different target elements. Principal component analysis (PCA) was employed to infer the potential sources of the target elements based on the compositional profiles and the physicochemical properties of these elements. This approach has emerged as a useful tool for better understanding of the relationships among metal concentration and food matrices and for revealing groups that are mutually correlated (Bhardwaj, 2017). Statistical analysis of the data was performed using SPSS (Version 23.0) and Origin.

2. **To integrate data on heavy metal concentrations with consumption patterns to estimate carcinogenic and non- carcinogenic risks in adult and children.**

A method for estimating the likelihood that a living being exposed to a hazardous medium may experience health problems or cancer over time is called a health risk assessment. First tier dietary risk assessment for heavy metals will be carried out for estimation of carcinogenic and non-carcinogenic risk associated with the food and water samples from Delhi. This will involve estimation of dietary intake of heavy metals and calculation of carcinogenic and non-carcinogenic risk indexes for both children and adults as given below:

Dietary Exposure and Risk Assessment

- **Dietary Exposure (Intake) Assessment**

Dietary intake of toxic and essential elements will be calculated for children and adults separately by using the following equation (Khan et al., 2013):

$$\mathbf{EDI = C_{metal} * C_{factor} * D_{food\ intake}\ BW\ldots\ (1)}$$

Where, EDI (mg/kg bw/day) is the estimated daily intake of a target element via diet based on the food items considered in this study. C_{metal} is the concentration of a target element (mg/kg) found in the food sample, C_{factor} is conversion factor to change fresh weight to dry weight, $D_{food\ intake}$ (g/ day) is daily intake/consumption rate of food item and BW is average body weight (kg/person) (which was on average considered to be 60 kg for adults and 35 kg for children).

Furthermore, EDIs will be compared with the maximum tolerable daily intakes (MTDI) specified by the European Food Safety Authority (EFSA CONTAM 2015) (EFSA CONTAM 2012) and tolerable/permissible thresholds (reference doses) specified by the United States Environmental Protection Agency (USEPA) (USEPA 2020).

- **Dietary Risk Assessment**

Dietary risk assessment of elements is a complex process considering they may have both acute and chronic effects, and may result in both genotoxic, carcinogenic or endocrinological outcomes. Moreover, the risk and effect also depend on the speciation of some of the elements, e.g., Cr (trivalent Cr is one of the essential inorganic metals for maintaining the human body whereas hexavalent Cr is genotoxic). Considering the limitations associated with dietary risk assessment of elements, in this study only a first-tier risk assessment will be performed for a selected number of toxic and essential elements (i.e. As, Ni, Cd, Pb, Hg, Cr, Cu, Mn, Mo, Zn, Co, Se)

- **Carcinogenic Risk Assessment**

For carcinogens, the risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. Cancer risk (CR) posed to human health by target toxic elements As, Ni, Cd, and Pb will be assessed as follows, according to (USEPA 1989)

$$\mathbf{CR = EDI * SF}$$

where SF is the slope factor for oral carcinogenic dose of toxic elements, (Kamunda et al. 2016).

The slope factor converts the EDI of elements averaged over a lifetime of exposure directly to the incremental risk of an individual developing cancer. This linear equation is based on the assumption that the dose-response relationship will be linear in the low-dose portion of the multistage model dose-response curve thus the slope factor is a constant, and risk will be directly related to intake.

- **Non-Cancerous Risk Assessment**

The non-cancer health risk associated with dietary intake of toxic and essential elements via consumption of the food items will be estimated using

Eq. 2 (USEPA 1989)

$$HQ = \frac{EDI}{R_f D} \qquad (2)$$

Where, HQ is non-cancer hazard quotient for chronic exposure (i.e., seven years to lifetime exposure) and RfD (mg/ kg bw/day) is oral reference dose of the target toxic element (USEPA 2020). Overall non-cancer hazard index (HI) posed to individuals through the diet (e.g. by consuming all food items based on their average daily consumption rates) will be determined using

Eq. 3 (USEPA 1989)

$$Hazard\,Index = \frac{E1}{RfD1} + \frac{E2}{RfD2} + \cdots \frac{Ei}{RfDi} \qquad (3)$$

where Ei = exposure level (or intake) for the ith element; RfDi = reference dose for the ith element; and E and RfD are expressed in the same units and represent the same exposure period. HI is basically the sum of non-cancer hazard quotients associated with the elements (i.e. As, Ni, Cd, Pb, Hg, Cr, Cu, Mn, Mo, Zn, Co, Se) under consideration. According to this statistical approach to risk assessment (USEPA 2001), when the hazard index exceeds unity, there may be concern for potential health effects.

3. **To estimate toxic heavy metals in soil irrigated with waste water and associated growing vegetables in Yamuna Belt in Delhi.**

There are various potential sources of heavy metals and their concentration and accumulation patterns get impacted by the effects of climate change. With drains being emptied into main rivers across Delhi and India, wastewater is a primary source of toxic metals in surface and drinking water. To study the effects and level of contamination, it has been planned to study supply water, groundwater and surface water (Yamuna River), select drains and soil irrigated with wastewater.

Heavy metals – Toxic (As, Cr, Cd, Pb, Hg, Ni) and Essential (Zn, Co, Mn, Cu, Se, Mo)

The detailed estimation will be conducted as above (1)

4. **Study of toxicity of heavy metals in human cell lines for assessment to Human Health.**

Depending on the dose and length of exposure, different heavy metals have different detrimental effects on the human body. This study will be designed to take into account various concentrations of toxic metals (any of these Ni, Pb, Cd) and will test them on human cell lines derived from the lung, liver, kidney or any other. The concentrations of metal introduced will also include the concentration estimated in the water sample to close the loop of the effects on human health.

5. **To review existing regulatory frameworks and guidelines related to heavy metals in food consumption.**

Effective management of heavy metal contamination in food systems requires a multifaceted approach. In addition to monitoring of contamination levels, it is important to analyze legal standards, monitoring programs of the government, and enforcement measures. Regulatory approaches to managing heavy metal contamination in food systems typically involve a combination of legal standards, monitoring programs, and enforcement measures. Here are some key elements commonly found in such regulatory frameworks and will be studied:

1. Setting Maximum Residue Limits (MRLs):

- Government of India or international bodies (like the Codex Alimentarius Commission) establish MRLs for heavy metals in various food products. These limits specify the maximum allowable concentration of a particular heavy metal (such as lead, cadmium, mercury, arsenic) in food. These limits are utilized for compliance as well as research purposes.

2. Monitoring and Surveillance:
    - Regular monitoring and surveillance programs are implemented to test food samples for heavy metal contamination. This helps in assessing compliance with MRLs and identifying contamination hotspots.
3. Risk Assessment and Management:
    - Governments/ researchers conduct risk assessments to assess the possible health risks related to eating food contaminated with heavy metals. Risk management strategies are then developed based on these assessments to mitigate identified risks.
4. Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs):
    - Agricultural and manufacturing practices that minimize heavy metal contamination are promoted and sometimes mandated through regulations. This includes proper use of fertilizers, soil management, irrigation water quality control, and manufacturing processes that prevent contamination.
5. Labeling Requirements:
    - Some jurisdictions require labeling of food products to indicate heavy metal content or compliance with regulatory standards. This informs consumers and facilitates market surveillance.
6. International Standards and Harmonization:
    - Harmonization of standards across countries (e.g., through Codex Alimentarius) ensures consistency and facilitates international trade while protecting public health.
7. Enforcement and Compliance:

- Regulatory agencies enforce compliance with established standards through inspections, product testing, and penalties for non-compliance. This helps deter unsafe practices and ensures adherence to safety standards.

8. Public Awareness and Education:
    - Public education campaigns raise awareness about the risks of heavy metal contamination in food and encourage safe consumption practices.
9. Research and Development:
    - Investment in research and development supports the development of new technologies and practices for detecting and reducing heavy metal contamination in food.

This part of the study would involve a comprehensive assessment of the regulatory framework, enforcement measures and limit of contaminants in the Indian context and draw inferences for good practices from the European context. Overall, effective management of heavy metal contamination in food systems requires a multifaceted approach that integrates regulatory standards, monitoring, enforcement, and public education to safeguard public health and ensure food safety.

EXPECTED OUTCOMES

The study aims to bring out a comprehensive data set for the concentration levels of toxic as well as essential heavy metals in the select food items (representative of the Indian food basket). This data would provide insight into the levels of toxic metals in the food consumed by the population of Delhi and whether they are above the permissible limits as prescribed by the regulatory authorities. This data would also feed into source apportionment studies to deduce the possible sources of contamination.

The overall study would benefit the city of Delhi and the entire country in mitigating the risk of contamination exposure through food consumption, especially among children, and contributing to developing policies and practices to reduce contamination exposure through diet.

The precise expected outcomes from the study are:

1. **Comprehensive Data on Heavy Metal Concentrations**

- Quantification of toxic (e.g., lead, cadmium, arsenic, mercury) and essential heavy metals (e.g., zinc, iron, copper) in selected food items representing the Delhi food basket.
- Identification of food categories with the highest contamination levels.

2. **Assessment of Toxic Metal Levels Against Regulatory Limits**

- Comparison of measured heavy metal concentrations with permissible limits set by regulatory authorities (e.g., FSSAI, WHO, FAO).
- Identification of food items that exceed safe consumption levels and pose potential health risks.

3. **Insight into Population Exposure in Delhi**

- Evaluation of dietary intake levels of heavy metals among Delhi's population, with a focus on vulnerable groups such as children.
- Estimation of potential health risks associated with long-term exposure.

4. **Source Apportionment of Heavy Metal Contamination**

- Identification of possible contamination sources (e.g., industrial pollution, agricultural practices, water contamination, packaging materials).
- Contribution to understanding environmental and anthropogenic factors influencing food contamination.

5. **Policy and Risk Mitigation Contributions**

- Recommendations for policymakers to establish or update food safety regulations and permissible limits.
- Suggestions for mitigation strategies to reduce heavy metal contamination in food supply chains.
- Potential guidance for consumers on minimizing dietary exposure.

6. **Public Health and Safety Impact**

- Enhanced awareness about heavy metal contamination risks.
- Support for initiatives aimed at reducing health hazards, particularly among vulnerable populations like children.

SIGNIFICANCE OF WORK

The present study is a comprehensive and systematic account of heavy metals for Indian food baskets, covering both peri-urban and urban population consumption patterns. The study encompasses the characterization of dietary intake of metals and the subsequent health risk assessment, which paves the way for future higher-tier risk assessment studies and can be used to complement ongoing works on dermal and inhalation risk assessment studies. The results from the levels of toxic metals would provide crucial information regarding the implications of mismanaged waste on the health of populations consuming items from that region. The objective of performing toxicity of select toxic metals directly on the concerned human cell lines would close the loop for this study, elucidating the impact of the levels found in food items on human health (cell line).

Overall, the data generated for detection levels and patterns of toxic metals from this study would feed into the actionable steps that regulatory authorities need to take for enhanced food security and management of environmental pollution of heavy metals. The results would also feed into the anticipated and upcoming Chemicals Management and Safety Rules of India.

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